Investigate the Boundary Layer Features in Beijing During the SURF-2015 Field Campaign

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Introduction

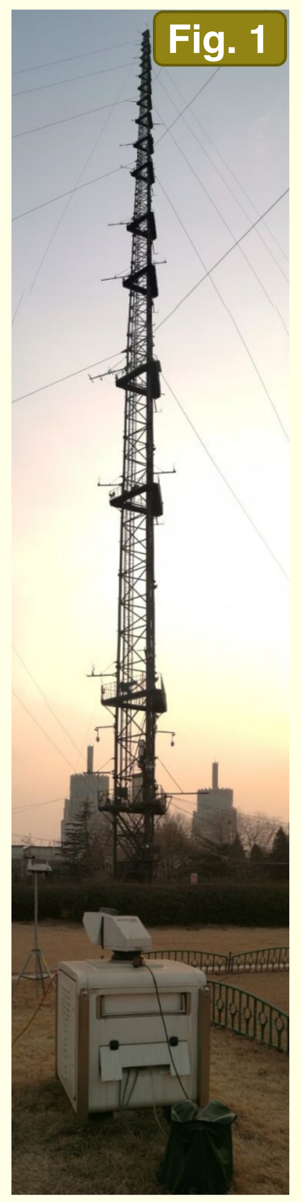
The Study of Urban-impacts on Rainfall and Fog/haze (SURF), led by the Institute of Urban Meteorology, China Meteorological Administration (IUM, CMA) is planned for the 2015-2017 summer and winter, focusing on the Beijing-Tianjin-Hebei city cluster. As part of SURF-2015, a high-resolution Doppler lidar and an instrumented 325-m meteorological tower (Fig. 1), collocated in the Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS), were used to sample the urban boundary layer (UBL) structure.

Objectives

- Determine urban PBL depth, an important variable for weather forecast and air quality modeling, under convective and nocturnal conditions
- Investigate the diurnal evolution of UBL

Lidar & Tower Data

- Lidar (Leosphere WindCube 100S) range is from 70-3000 m with 20-m vertical resolution. Only data satisfying the threshold carrier-to-noise ratio (CNR) of -20 dB were used.
- IAP tower sensors include 7-level 3-D sonic anemometers (Windmaster Pro) and open-path gas analyzers (LI-7500A) at 10-Hz frequency.
- Study period: 5-8 Jul & 12-13 Aug (only dates with complete lidar data)



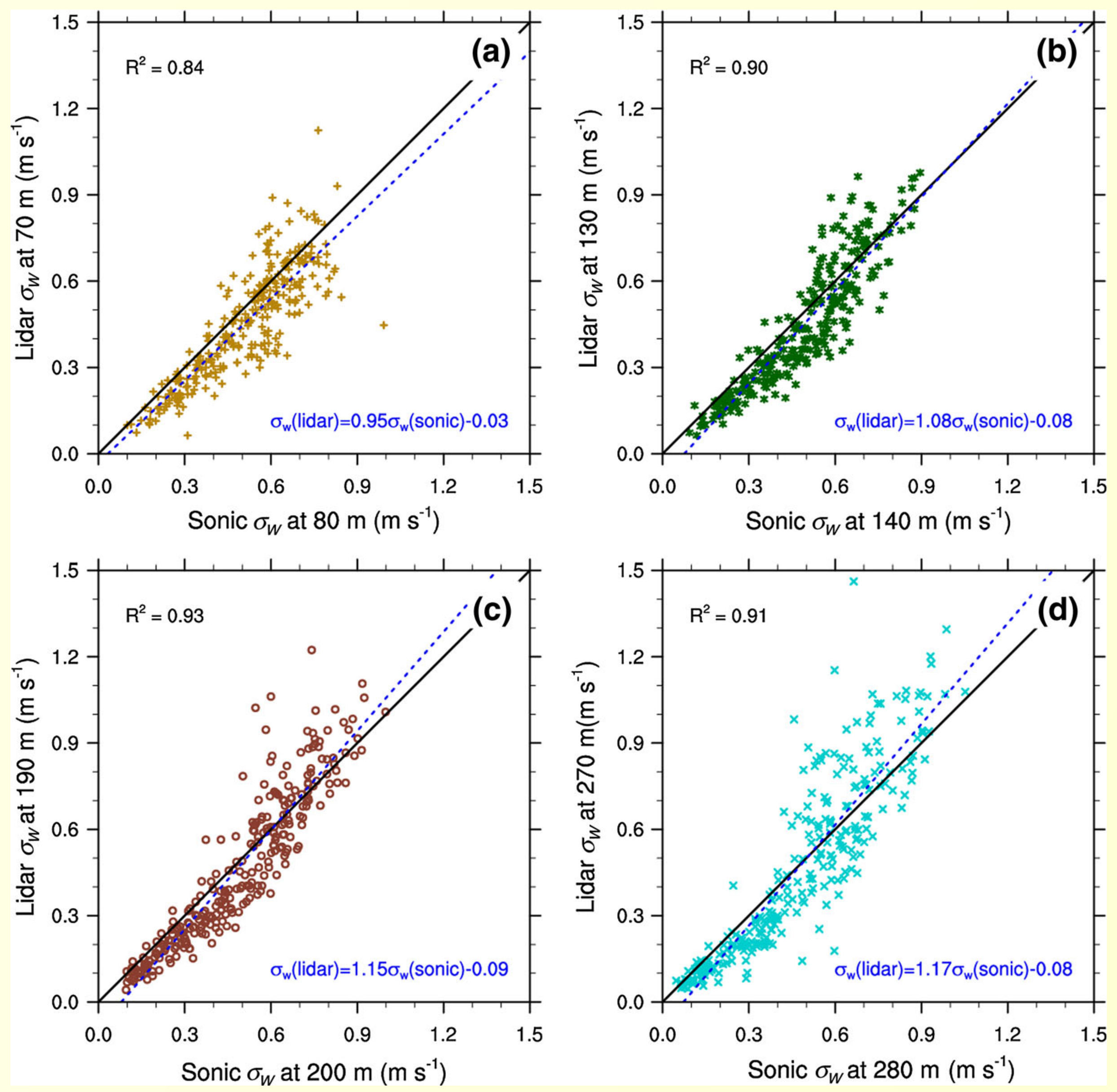


Fig. 2 Comparisons of $\sigma_w = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(w_i - \overline{w})}$ between lidar data and 30-min sonic-anemometers averages at four different heights.

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Determining Urban PBL Depth

1. Threshold method for convective BL

The lidar 30-m vertical velocity variance was used to determine the PBL depth. Following Barlow et al. [2011], threshold value is 0.1 m^2 s^{-2} for an urban environment. An example of employing this threshold is shown in Fig. 3.

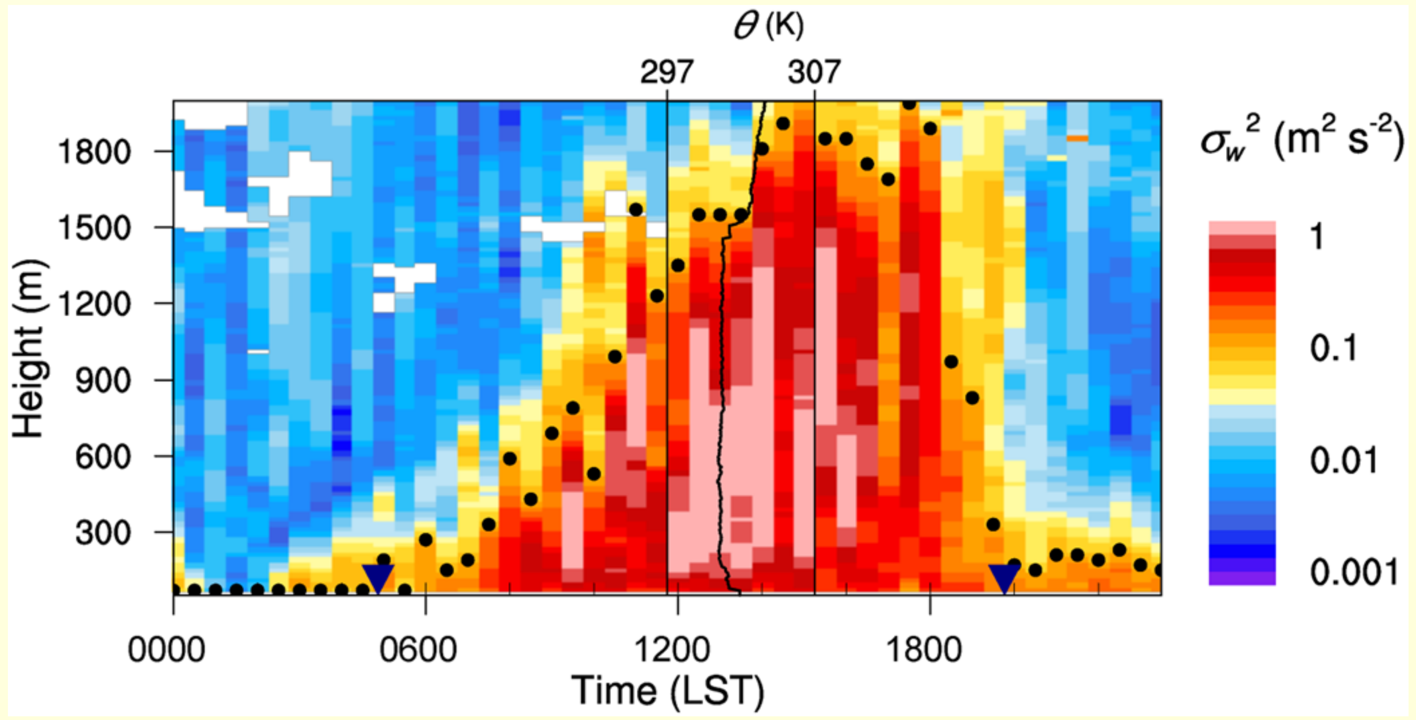

Fig. 3 30-min averaged σ_w^2 calculated from DBS data on 6 July 2015. PBL depths based on threshold method are indicated by black dots. Also displayed is the potential temperature (θ) profile based on the 1315 LST sounding released at Nanjiao, which is also an urban site but located 20 km southeast of IAP.

However, the threshold method failed to determine the nocturnal boundary layer (NBL), especially for late night (0000-0500 LST). This motivates to explore another techniques for estimating NBL depths.

2. Fractional method for nocturnal BL

The nocturnal turbulence regime for SURF-2015 is identified to be near-neutral regime based on the Sun et al. [2012] definition. Thus, we use a slightly altered version of the LeMone et al. [2014] method, which defines the NBL top as the height at which TKE decreases to a specific fraction of its near-surface maximum after subtracting out a "background" (free atmosphere) value (Fig. 4).

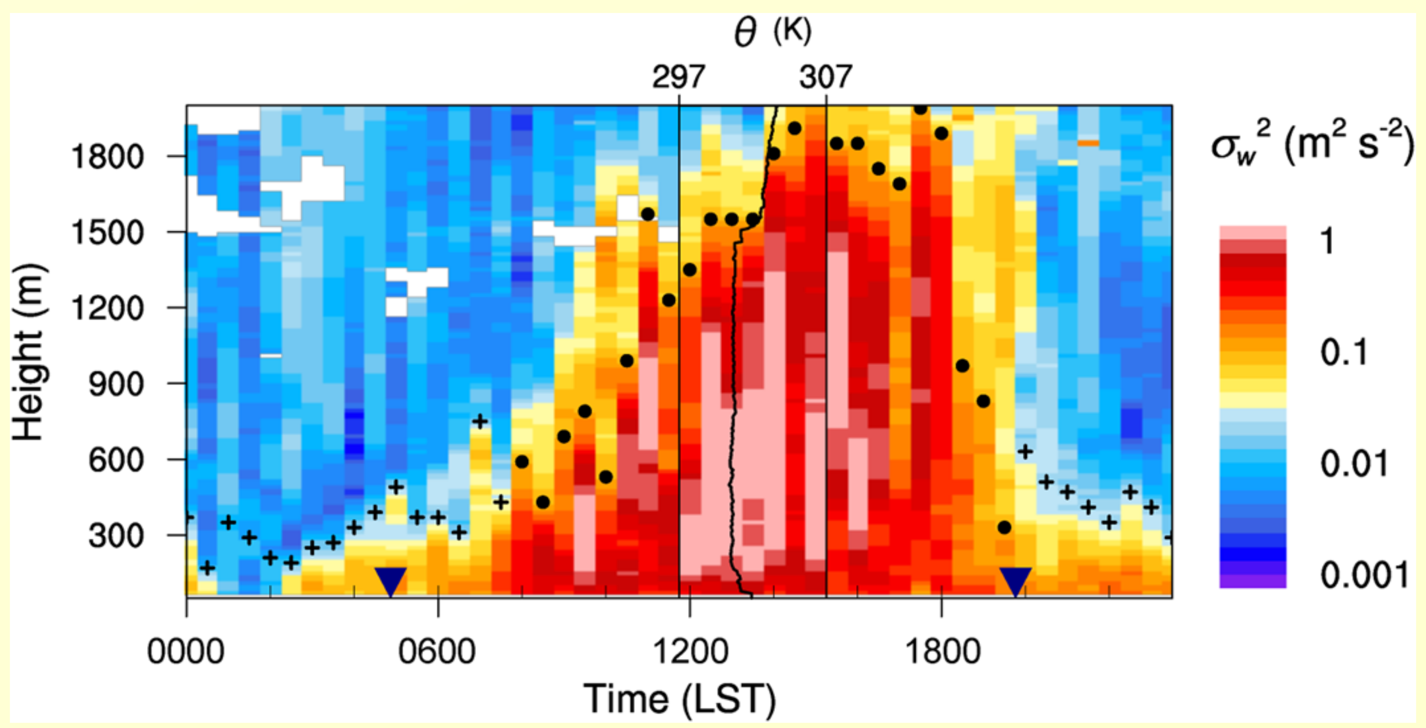

Fig. 4 Same as Fig. 3 for 6 July, except that the fractional method is used for the NBL estimate, denoted with a plus.

WRF-Urban Simulations

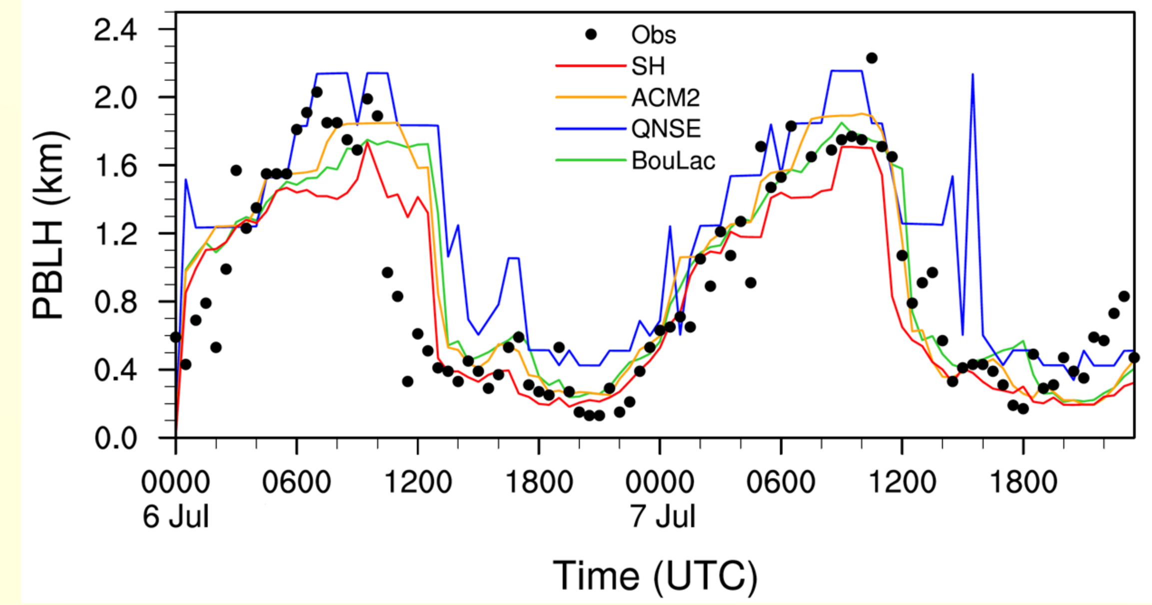

Fig. 5 Time series of the PBL depths from four schemes (lines) and observations (dots).

❖ **Results-1: PBLH**

- Smaller critical Ri_b reduces the turbulent intensity by weakening the entrainment of free-tropospheric air into the PBL and thus predicted lower PBL depths. (SH & ACM2)
- Threshold TKE value in QNSE (0.005) may be too small for urban areas. Irregular growth of NBL implies the threshold-based method may be not applicable for NBL.
- BouLac on 7 July is the closest to observation.

❖ **Results-2: Eddy viscosity & eddy diffusivity**

- K_M shows its maximum at around 550 m above the ground (except for QNSE) but with different magnitudes.
- QNSE shows a shallower mixing than other three schemes and artificially weak mixing in the upper part of PBL.

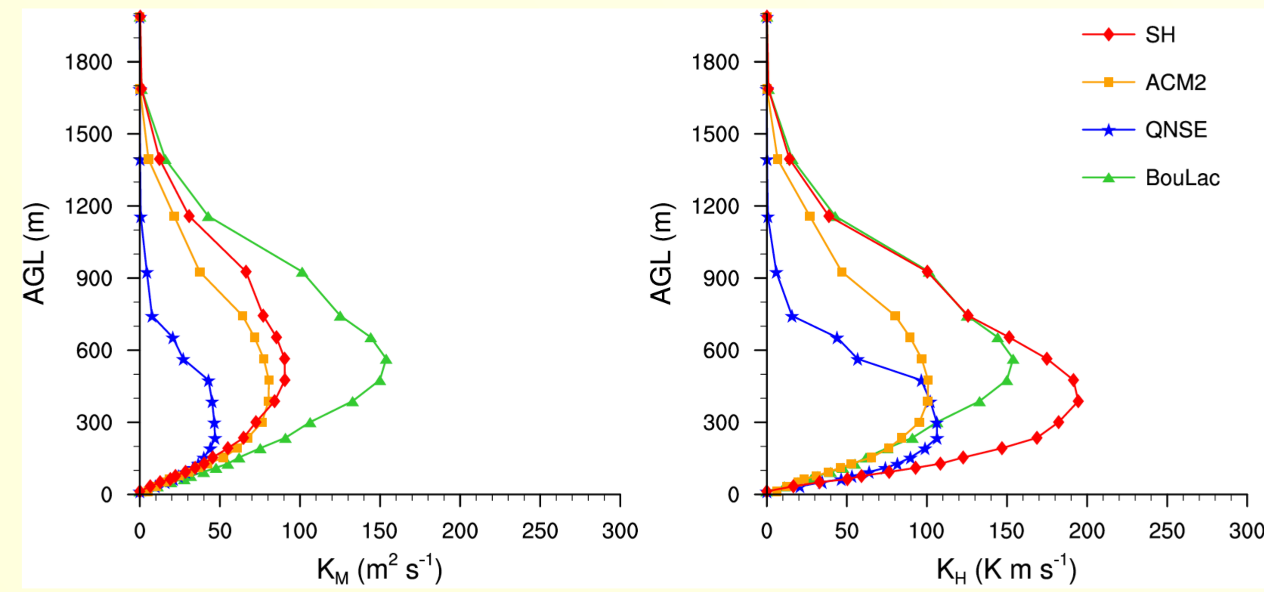

Fig. 6 Exchange coefficients averaged from 2200 UTC 6 July (0600 LST 7 July) to 1100 UTC 7 July (i.e., convective regime).

Conclusions & Future Work

- The PBL evolution in urban areas is studied by combining 6-day Doppler lidar wind measurements and observations from the 325-m IAP tower during the summer SURF-2015 field campaign.
- We developed a composite method for estimating the PBL depths using the Doppler lidar.
  - CBL: $\sigma_w^2 < 0.1$ m^2 s^{-2}
  - NBL: $\sigma_w^2 = 0.1 * (\sigma_{wmax}^2 - \sigma_{wb}^2) + \sigma_{wb}^2$, where $\sigma_{wb}^2 = 0.01$ m^2 s^{-2}
- The PBL depths determined by combining these methods have average values ranging from ~270 m to ~1500 m for the six days.
- Overall, the PBL evolution in urban areas is well captured by WRF-Urban with different PBL schemes, except for the QNSE scheme.
- The following tasks are planned:
  - Optimize the QNSE parameterization
  - Analyze the effects of Urban Canopy Models and regarding urban parameters on PBL evolution

References

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